



Software Cost Estimation



Jet Propulsion Laboratory

Case Study Part B

Sizing the System

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Sizing the System



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The purpose of this exercise is to generate a size estimate for a hypothetical software project for the purposes of generating a cost estimate



Sizing the System



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In this exercise, we will:

1. **Measure the size of reference code** to be used in the size estimation process
2. **Estimate** the amount new code development, reuse, and modification
3. **Generate a probabilistic estimate of equivalent size** for the new software project



Project Description



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1. JPL is developing flight software (FSW) for a flight project. It is a telecom system that can be reused by landers and rovers for communicating with earth.
2. The flight software's can be divided into four primary function: monitoring data , data transfer, command and control, and relay communication.
3. The telecom system has some design heritage with an existing telecom system that has been developed. There is a small amount of code inheritance. All new code developed will be in C.
4. A software development environment including a test-bed exists.
5. The software is nearing its preliminary design review (PDR). The software must be delivered to ATLO in 16 months (64 weeks), with a small, though experienced (3 years C experience, but very little experience in the development tools), development staff.
6. Requirements are immature, therefore 10-20% requirement volatility is expected.
7. There is concurrent HW development. The HW is being developed by a contractor in another state.
8. This will be mission class B (Mission Critical) software.
9. The project is currently budgeted at 54 WM. IV&V is paid for at the project-level, and the cost of maintenance does not need to be included.

This example of a JPL software development project is loosely based on a real project. It is meant to illustrate the basic steps of developing a software estimate. It is not intended to serve as a source for answers to all questions that may arise regarding software estimation.



Part 1 – Measure Reference Code Size



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The first step in the sizing process is to identify and measure the size of reference (analogy) code

In this exercise, we will use the JPL SLiC code counter to measure the size of four different software functions that have been identified as reference modules:

1. Monitor Data ([Function W](#))
2. Data Transfer ([Function X](#))
3. Command and Control ([Function Y](#))
4. Relay Communication ([Function Z](#))



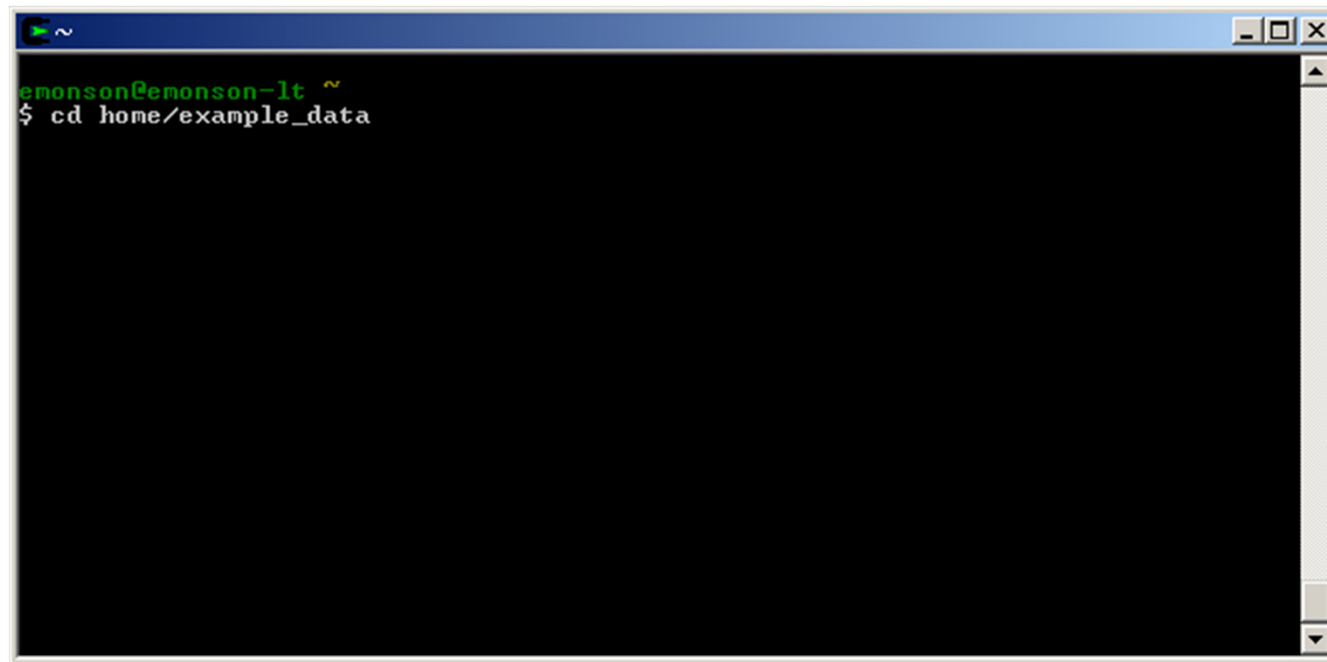
Count Reference Code



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Note: Sample code (Functions W,X,Y,Z) has been loaded on the training PCs for this example

1. Double-click on the 'Cygwin' desktop icon 
2. Enter: `cd example_data` at the prompt and press 'ENTER' to move to the folder with the example data



```
emonson@emonson-lt ~  
$ cd home/example_data
```



Count Reference Code (cont'd)



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At this point, you are in the `example_files` folder, which contains sub-folders containing our sample reference code:

- `example_w`
- `example_x`
- `example_y`
- `example_z`

To verify that you are in the correct location, type `ls -l` at the prompt and press ENTER. You should see a window similar to below:

```
~/example_data
emonson@emonson-lt ~/example_data
$ ls -l
total 721
-rw-r--r--  1 emonson mkggroup-l-d   140 Oct  5 10:53 README
drwxr-xr-x+ 2 emonson mkggroup-l-d  8192 Oct  5 10:39 function_w
drwxr-xr-x+ 2 emonson mkggroup-l-d 12288 Oct  5 10:41 function_x
drwxr-xr-x+ 5 emonson mkggroup-l-d 12288 Oct  5 10:44 function_y
drwxr-xr-x+ 3 emonson mkggroup-l-d  4096 Oct  5 10:50 function_z
-rwxr-xr-x  1 emonson mkggroup-l-d 698593 Oct  5 15:02 slic.exe

emonson@emonson-lt ~/example_data
$ _
```



Count Reference Code (cont'd)



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Now that we are in the root folder (with all reference code below us), let's perform a count of all source:

```
$ ./slic -t
```

```
~/example_data
total 721
-rw-r--r-- 1 emonson mkggroup-1-d 140 Oct 5 10:53 README
drwxr-xr-x+ 2 emonson mkggroup-1-d 8192 Oct 5 10:39 function_w
drwxr-xr-x+ 2 emonson mkggroup-1-d 12288 Oct 5 10:41 function_x
drwxr-xr-x+ 5 emonson mkggroup-1-d 12288 Oct 5 10:44 function_y
drwxr-xr-x+ 3 emonson mkggroup-1-d 4096 Oct 5 10:50 function_z
-rwxr-xr-x 1 emonson mkggroup-1-d 698593 Oct 5 15:02 slic.exe

emonson@emonson-1t ~/example_data
$ ./slic -t

RESULTS FOR ALL SUB-DIRECTORIES UNDER:
.
```

	LANG	FILE SIZE	COM- MENTS	LOG SLOC	PHY SLOC	PHY SLOC
TOTAL	C	1.7 MB	16.0k	30.6k	43.1k	68.4k
GRAND TOTAL	---	1.7 MB	16.0k	30.6k	43.1k	68.4k

```
emonson@emonson-1t ~/example_data
$
```

30,600 logical
SLOC in
Functions
W,X,Y,Z

By default, SLiC automatically finds and counts all supported source code under the current path



Count Reference Code (cont'd)



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The next step is to count at the first subfolder level

This command shows the SLOC totals for each function (folder):

```
$ ./slic --output-depth=1
```

The *output-depth* option displays totals (totaled recursively) at depth *d* relative to the current (or explicitly specified) path

```
~/example_data
emonson@emonson-1t ~/example_data
$ ./slic --output-depth=1

RESULTS FOR ALL SUB-DIRECTORIES UNDER:
./function_w

      LANG      FILE SIZE      COM-      LOG      PHY      RAW
      -----      -----      -MENTS-      SLOC      SLOC      SLOC
      -----      -----
GRAND TOTAL      ---      334.3 kB      3.1k      6.1k      8.9k      14.2k

RESULTS FOR ALL SUB-DIRECTORIES UNDER:
./function_x

      LANG      FILE SIZE      COM-      LOG      PHY      RAW
      -----      -----      -MENTS-      SLOC      SLOC      SLOC
      -----      -----
GRAND TOTAL      ---      768.3 kB      7.3k      13.4k      17.8k      29.5k

RESULTS FOR ALL SUB-DIRECTORIES UNDER:
./function_y

      LANG      FILE SIZE      COM-      LOG      PHY      RAW
      -----      -----      -MENTS-      SLOC      SLOC      SLOC
      -----      -----
GRAND TOTAL      ---      440.0 kB      4.7k      6.8k      9.9k      16.0k

RESULTS FOR ALL SUB-DIRECTORIES UNDER:
./function_z

      LANG      FILE SIZE      COM-      LOG      PHY      RAW
      -----      -----      -MENTS-      SLOC      SLOC      SLOC
      -----      -----
GRAND TOTAL      ---      215.2 kB      999      4.3k      6.4k      8.7k

emonson@emonson-1t ~/example_data
$ -
```



Compute Total SLOC



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- Compute Total SLOC based on
 - Monte Carlo Simulation
- Step 1: Open MonteCarloSizing Tool (On Desktop in folder named “QSM” and [today’s date])
- Step 2: Enter Size numbers from previous slide into tool in historical column
- Step 3: Scale your software size to the reference sizes
- Step 4: Run Monte Carlo Simulation
- Step 5: Save your results for the next exercise

This column contains the logical SLOC we estimated from SLiC

Microsoft Excel - MonteCarloSizing10-05-05ExerciseB.xls															
Type only in yellow-colored and green-colored cells; white cells are calculated for you.															
Enter Name of Segment or Function	Historical/Reference Project Actual SLOC	Type of Distribution for New SLOC	New SLOC			New Mean	Type of Distribution for Reused SLOC	Reused SLOC	% Modified of Reused			% Modified Mean	Reused Mean	Total Eq SLOC	Basis of Estimate/Comments
		Click on Cell to Select from Drop-Down	Low	Likely	High		Click on Cell to Select from Drop-Down		Low	ML	High				
Monitor Data	6100	Triangular Distribution (L, ML, H)	3050	4270	6100	4473	Uniform Distribution (L, H)	0				0%	0	4473	All new code. At most same size as Historical Project V. Will perform slightly simpler functionality. 50% of historical project at the least, 70% of functionality is most likely.
Data Transfer	13400	Uniform Distribution (L, H)	3350		6700	5025	Uniform Distribution (L, H)	0				0%	0	5025	All new code. Only 25-50% of data transfer functionality will be required compared to the Historical Project V. The other 50-75% of Project V is not applicable to Telecom projects.
Command and Control	6800	Triangular Distribution (L, ML, H)	3400	3740	4420	3853	Uniform Distribution (L, H)	3400	0%		5%	3%	860	4714	Will reuse 50% of Historical Project V with little to no mods (0-5%). Other 50% will write all new, with possible 5-10% additional functionality.
Relay Communication	4300	Uniform Distribution (L, H)	3010		3440	3225	Triangular Distribution (L, ML, H)	1290	20%	30%	50%	33%	533	3758	Will reuse 30% of Historical Project 2 with major mods (20%), 30%ML, 50%H. Other 70% of functionality will be written all new with an increase of about 10% functionality at the most.
Function5		Triangular Distribution (L, ML, H)				0	Uniform Distribution (L, H)					0%	0	0	
Function6		Triangular Distribution (L, ML, H)				0	Uniform Distribution (L, H)					0%	0	0	
Function7		Triangular Distribution (L, ML, H)				0	Uniform Distribution (L, H)					0%	0	0	
Function8		Triangular Distribution (L, ML, H)				0	Uniform Distribution (L, H)					0%	0	0	
Function9		Triangular Distribution (L, ML, H)				0	Uniform Distribution (L, H)					0%	0	0	
Function10		Triangular Distribution (L, ML, H)				0	Uniform Distribution (L, H)					0%	0	0	
Function11		Triangular Distribution (L, ML, H)				0	Uniform Distribution (L, H)					0%	0	0	
Function12		Triangular Distribution (L, ML, H)				0	Uniform Distribution (L, H)					0%	0	0	
Function13		Triangular Distribution (L, ML, H)				0	Uniform Distribution (L, H)					0%	0	0	
Function14		Triangular Distribution (L, ML, H)				0	Uniform Distribution (L, H)					0%	0	0	
Function15		Triangular Distribution (L, ML, H)				0	Uniform Distribution (L, H)					0%	0	0	
Total Equivalent Size (Mean Point Estimate)														17970	
Run Monte Carlo Clear Inputs Change Number of Iterations															

Technology



MonteCarloSizing Tool



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- Excel-based tool to help you with your analogy size estimates
- Incorporates uncertainty by allowing distributional inputs
- Choose between point estimates, uniform inputs (Low and High), or triangular inputs (Low, Most Likely, and High)
- Uses Monte Carlo techniques to aggregate size and compute total equivalent size
- Can choose number of iterations per Monte Carlo run – 9,999 iterations is recommended
- Other features: Function Point Calculator that allows distributional inputs for uncertainty



Scaling the Software Size



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- Estimate Size Distribution parameters
 - Convert to logical lines if needed
 - Derive ML based on analogous functions from completed software systems
 - Adjust estimate for differences between current fn and analogous fn
 - Estimate low and high estimates based on best and worst case scenarios and document basis of estimate

Read the basis of estimate to fill in missing size estimates

	A	B	
1	Type only in yellow-colored and green-colored cells; white in gray-colored cells		
2	Enter Name of	Historical/Reference	
3	Segment or Function	Project Actual SLOC	Basis of Estimate/Comments
4	Monitor Data	6100	All new code. At most Same size as Historical Project W. Will perform slightly simpler functionality, 50% of historical project at the least, 70% of functionality is most likely.
5	Data Transfer	13400	All new code. Only 25-50% of data transfer functionality will be required compared to the Historical Project X. The other 50-75% of Project X is not applicable to Telecom projects.
6	Command and Control	6800	Will reuse 50% of Historical Project Y with little to no mods (0-5%). Other 50% will write all new, with possible 5-15% additional functionality of Historical Project Y.
7	Relay Communication	4300	Will reuse 30% of Historical Project Z with major mods (25%L, 30%ML, 50%H). Other 70% of functionality will be written all new with an increase of about 10% functionality of Historical Project Z at the most.
8	Function5		technology



Sample Size Analogy Inputs



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Microsoft Excel - MonteC

File Edit View Insert

Window Help

F6

A

1 Type only in yellow-colored ar

2 Enter **Name** of

3 Segment or Function

4 Monitor Data

5 Data Transfer

6 Command and Control

7 Relay Communication

8 Function5

cells are calculated for you:

Type of Distribuion for New SLOC	New SLOC			New	Type of Distribuion for Reused SLOC	Reused	% Modified of Reused%		
Click on Cell to Select from Drop-Down	Low	Likely	High	Mean	Click on Cell to Select from Drop-Down	SLOC	Low	ML	High
Triangular Distribution (L, ML, H)	3050	4270	6100	4473	Uniform Distribution (L, H)	0			
Uniform Distribution (L, H)	3350		6700	5025	Uniform Distribution (L, H)	0			
Triangular Distribution (L, ML, H)	3400	3740	4420	3853	Uniform Distribution (L, H)	3400	0%		5%
Uniform Distribution (L, H)	3010		3440	3225	Triangular Distribution (L, ML, H)	1290	20%	30%	50%
Triangular Distribution (L, ML, H)				0	Uniform Distribution (L, H)				

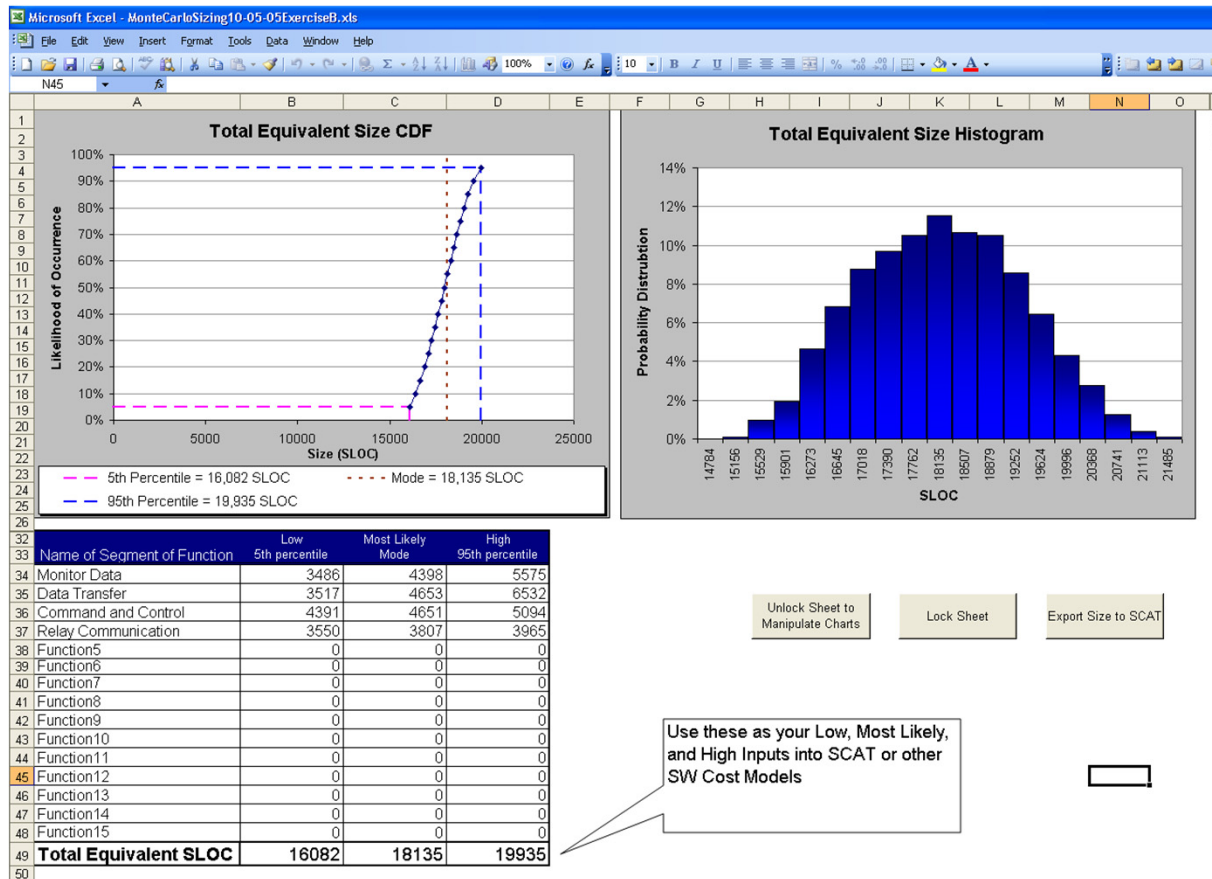
Choose between point estimates, uniform inputs (Low and High), or triangular inputs (Low, Most Likely, and High)



MonteCarloSizing Tool Output



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Note: Output numbers will vary slightly due to randomness of draws

- MonteCarloSizing Tool outputs a Low, Most Likely, and High Equivalent Size estimate
- Save your results for the next exercise